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EFFECT OF DIFFERENT ENERGY LEVELS (USING PLANT DRY FAT), AND PELLETED FEED ON THE PERFORMANCE OF HEAT-STRESSED BROILER CHICKENS

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Faculty of Graduate Studies

The University of Jordan

تعتمد كلية الدراسات العليا
هذه النسخة من الرسالة
التوقيع.......التاريخ.......

May, 2011

This Thesis (Effect of Different Energy Levels (Using Plant Dry Fat), and Pelleted Feed on the Performance of Heat-Stressed Broiler Chickens) was successfully defended and approved on April 25th. 2011

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تعتمد كلية الدراسات العليا
هذه النسخة من الرسالة
التوقيع......التاريخ......

DEDICATION

To my parents,

brothers and sisters.

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LIST OF ABBREVIATIONS

CHO	Carbohydrates
g	Gram
HDL	High Density Lipoprotein
kcal	Kilocalorie
kg	Kilogram
LDL	Low Density Lipoprotein
ME	Metabolizable Energy
MJ	Megajoule
RITr	Rate of Increase of Rectal Temperature
VLDL	Very Low Density Lipoprotein

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ABSTRACT

An experiment was conducted at the poultry farm at the University of Jordan Station for Dry Land Research, to investigate the effect of different dietary fat levels and feed form on heat-stressed broiler chickens.

A total of 900 Lohmann straight-run broiler chicks were reared from 28-42 days of age. At the beginning of the experiment, birds were randomly allotted to two groups, each containing 450 chicks, and exposed to either variable-natural temperature (17-25°C) in an open-sided poultry house, or under constant heat stress (35±1°C) in an environmentally controlled poultry house. Birds from each group were fed six diets containig 18% crude protein, supplemented with 2, 4, or 6% of plant dry fat as the supplemental energy source (no soybean oil was added). Each of the three diets was fed in two feed forms, either mash or pellets.

Results showed that broilers performance was generally depressed by heat stress, regardless of dietary fat percentage or feed form. Under both temperatures, dietary fat percentage did not improve broiler performance (when given in the same feed form). Also, feed pelleting did not improve broiler performance compared to mash diets (within the same fat percentage). Dressing percentage decreased ($P<0.05$) under heat stress when the pelleted 6% fat diet was fed, while no differences were observed within the natural temperature. Abdominal fat was not affected by ambient temperature. The different treatments generally had no significant effect on meat quality traits or blood parameters measured, except that heat stress decreased ($P<0.05$) meat pH. Results also showed that heat exposure improved broilers heat tolerance.

1. INTRODUCTION

Poultry sector in Jordan has grown rapidly in the last few years. Annual reports of Ministry of Agriculture show that poultry meat production increased from 97.8 to 169 thousand tons between 1997 and 2010, while consumption increased from 99.8 to 201 thousand tons. This increase in production and consumption is attributed to an increase in population and growing annual poultry meat consumption (per capita), which increased from 22.7 kg to 29 kg in the same period mentioned above. These figures show the importance of further development and improvement of poultry production to meet the high demand and minimize importing.

Jordan is located within an arid to semi arid region. The ambient temperature in summer may exceed the optimum range recommended for broiler production, which could be detrimental, since most modern genetic strains of poultry have been developed and improved in temperate climates. Extension of the commercial range of these modern genetic strains to other countries has created the necessity of reevaluating their nutrient requirements to enable them to perform satisfactorily at high ambient temperature, since nutrition is considered as one of the strategies to reduce the effects of heat stress. Poultry sector in Jordan is under the threat of losses resulting from heat stress, especially sudden heat waves. Al-Fataftah (1987a) reported mortality exceeding 40% of market age broilers at the University of Jordan farm located at Jordan valley in August 1985, resulted from a heat wave that lasted for three days, and the maximum temperature recorded was 45.8°C.

Hot environment is one of the most important stress factors in poultry production. The resultant heat stress comes from the interactions among air temperature, humidity, radiant heat and air speed, where the air temperature plays the major role. Like all homeotherms, broilers are able to maintain a normal body temperature and their

performance is most efficient within comfort zone (18-22°C) where heat balance and exchange impose no stress on the bird. The term ``heat stress`` is often used to define the bird`s response to high ambient temperature (above 22°C), where some abnormal responses are observed. Broiler chicken producers rarely worry about heat stress with broilers less than 4 weeks of age, but do so as the bird gets older. Broiler chickens respond adversely to a hot environment through decreasing feed intake and rate of body weight gain, and increasing body fat deposition (Yahav *et al*., 1996). Feed intake has been estimated to decrease by about 3.6% per degree increase between 22 and 32°C (Ain Baziz *et al.,* 1996). Birds also exhibit panting and wing lifting behaviour when they have difficulty dissipating the heat generated by digestion and energy metabolism, as they have no sweat glands. In addition, their respiratory water evaporation rate is not high enough to maintain normalthermia at high ambient temperatures (Dawson and Whittow, 2000).

In order to alleviate the detrimental effects of high environmental temperature on poultry performance, several corrective approaches have been applied and others are still under investigation. Among these various approaches the dietary manipulations, such as increasing nutrient density, alteration of energy: protein ratio, improvement of the dietary amino acid profile, the addition of extra vitamins, alteration in the dietary anion:cation balance, and changing the proportions of energy supplied as lipid and carbohydrate.

The reduction in feed intake at high ambient temperature usually leads to nutrient limitation among which energy is the most important. The first priority for dietary energy is maintenance which increases under heat stress, and the remaining energy goes for growth and tissue accretion. Hurwitz *et al*. (1980) studied energy requirements in young chicks at different ambient temperature, ranging from 12 to

32°C. The maintenance requirement decreased with constant temperatures from 12 to 24°C, reaching its lowest value between 24 and 28°C, followed by an increase as temperature was raised further. Therefore, any limitation in dietary energy intake results in reduced growth and tissue accretion (Veldkamp *et al*., 2005).

Dale and Fuller (1979) increased diet density (increased percent of energy derived from fat) through replacing corn starch with fat. They concluded that diet would be utilized better with the high density diets. Supplementing diets with fat has other advantages as well; it decreases dustiness of feeds, increases feed palatability and lubricates equipments in feed mills. Unsaturated vegetable oils are used in poultry diets as they have higher metabolizable energy (ME) value than that of animal fat or products with high free fatty acids (Waldroup *et al*., 1995).

In many studies, feed pelleting was found to be beneficial; it resulted in a large growth response and a moderate improvement in feed efficiency in both broiler chickens and turkeys (Plavnik *et al*., 1997). Feed efficiency or feed conversion ratio was improved by feeding crumbled pellets as compared to all-mash diets for broilers (McNaughton and Reece, 1984). The number of meals consumed per day was the same for pelleted and mash feeds, but the duration of each meal was reduced three-fold in chickens fed pellets. This means that offering pelleted feed to broilers can result in a 67% reduction in the energy required for eating (Jensen *et al.*, 1962).

The objective of this study is to evaluate the effects of different dietary fat levels using plant dry fat in the form of mash or pelleted diets on the performance, carcass yield, composition and quality of meat, in addition to some physiological and blood parameters of 4-6 weeks old broiler chickens under heat stress.

2. LITERATURE REVIEW

2.1. EFFECT OF HEAT STRESS ON BROILERS PERFORMANCE AND CARCASS QUALITY

2.1.1. BODY WEIGHT AND WEIGHT GAIN

Hurwitz *et al.* (1980) reported that for broilers raised between 19 and 34°C, weight gain decreased linearly with temperature elevation. Cerniglia *et al*. (1983) reared Cobb broilers under various constant ambient temperatures, at four weeks of age, and found that birds reared at 24°C gained more weight than those reared at 35°C. Hacina *et al*. (1996) reported that body weight of broilers reared at 32°C was 47% less than that of broilers reared at 22°C. Geraert *et al*. (1996) studied the effects of chronic heat exposure (constant 32°C) on chicks growth, and reported that the chicks had less weight gain (659g) than those reared at 22°C (1115g).

Yahav *et al.* (1996) investigated the effect of constant and diurnal cyclic temperatures on broiler performance. Cobb broiler chickens were exposed to a cyclic temperature of 10 to 30°C and constant environmental temperatures of 10, 20 and 30°C. They found that at constant temperatures, weight gain was significantly ($P<0.05$) higher in chickens exposed to 20 than 10°C, but those exposed to 30°C had less weight gain. Chickens exposed to cyclic temperatures of 10 to 30°C had significantly lower weight gain compared with those exposed to constant 20°C. They also cited that growth rate was reduced by 4.5, 34 and 17% at 10, 30 and 10 to 30°C, respectively.

2.1.2. FEED INTAKE

Cowan and Michie (1978) found that feed intake of female broilers decreased 43 g per bird per one degree increase in ambient temperature from 10-21°C, 73 g from 21-26°C, and 119 g from 26-31°C. Alfataftah (1987b) reported that decreasing feed intake with increasing environmental temperature might be due to a decrease in metabolic rate, which consequently decreases heat production so that birds can maintain their body

temperature within normal limits. Yahav *et al*. (1996) reported a reduction in feed intake by 10, 20, and 46% when ambient temperature increased from 20°C to 25, 30, and 35°C, respectively.

Generally, the decrease in feed intake is derived from the diminished energy requirement for maintenance as revealed by the decrease in oxygen consumption or heat production, and is related to the ability of birds to regulate their energy intake to meet their specific need. Kamal (1975) reported that high environmental temperature stimulates the peripheral thermal receptors to transmit suppressive nerve impulse to the appetite center in the hypothalamus leading to a decrease in feed consumption. Thus, fewer substrates will be available for enzymatic activities, hormone synthesis and heat production, which helps to minimize heat load.

2.1.3. FEED CONVERSION RATIO

Hurwitz *et al*. (1980) reported that feed efficiency increased with temperature to reach maximum at 27°C, and then decreased between 27 and 34°C. Al-Fataftah (1987b) reported that the optimum environmental temperature range to obtain the best feed conversion ratio was 12.7-26.7°C. Meltzer (1986) studied the efficiency of feed utilization in seven consecutive flocks of male broilers grown in an environment controlled poultry house. He concluded that temperatures above 28°C negatively affect feed conversion ratio.

The poor feed conversion ratio at high ambient temperatures could be attributed to decreased efficiency of utilization of feed energy for productive purposes (Al-Fataftah, 1978b; Yahav, 1996).

2.1.4. MORTALITY

May *et al*. (1987) reported that when acclimated broilers were exposed to temperature of 41°C for 3.5 hours, they had lower mortality rate than the control

(unacclimated) birds. Mortality rate was 10% for acclimated broilers and 30% for the control birds. Arjona *et al*. (1988) found that exposure of broiler cockerels to a temperature of 35-38°C for 24 hours at the age of five days decreased mortality rate resulting from a heat stress lasted for 8 hours at the age of 44 and 45 days.

Eberhart and Washburn (1993) reported that lines selected for fast growth had significantly higher mortality rates under high temperature stress than lines selected for slow growth. However, other researchers found that mortality was not affected by heat stress. Sinurat and Balnave (1985) found no significant differences in mortality of broilers kept under cyclic high ambient temperatures (25-35°C) compared to those kept under cyclic moderate ambient temperatures (18-26°C).

2.1.5. CARCASS YIELD AND COMPOSITION

Hurwitz *et al*. (1980) found that ambient temperature had no significant effect on abdominal fat of broilers kept under different ambient temperatures (12, 19, 28, and 34°C). Also, Sinurat and Balnave (1985) reported that ambient temperature had no significant effect on abdominal fat content of broilers kept at cyclic moderate (18-26°C) or cyclic high ambient temperatures (25-35°C).

Sonaiya *et al*. (1990) reared broilers under cyclic high temperature (21-30°C) or under constant low temperature (21°C). Birds were fed two diets of 13.0 MJ/kg (low energy) or 13.8 MJ/kg (high energy). They reported that the high temperature resulted in higher breast and lower leg proportions of broilers compared to those reared under the low temperature.

Cahaner *et al*. (1992) studied the slaughter yield and breast meat proportion of 6 weeks old broilers reared at 20°C, and 8 weeks old broilers reared at constant 32°C. They found that the high temperature increased dressing percentage and reduced breast meat proportion.

Smith (1993a) conducted a study to examine the effects of cyclic high environmental temperature during the growing period on carcass yield. Broilers were reared from 23 to 49 days of age at either 23.9°C constant temperature or 23.9-35°C cyclic temperature. Birds in the hot environment had lower carcass and breast weights, also lower breast yield compared to those reared under thermoneutral conditions.

Yahav *et al*. (1996) reported increased abdominal fat pad with increasing environmental temperature in chickens exposed to cyclic temperature of 10-30°C compared with constant 10, 20 and 30°C. They found that abdominal fat mass increased linearly with the increase of ambient temperature. Also, broilers exposed to 15-30°C deposited less abdominal fat and breast muscle than those kept at a constant temperature of 25°C. Yahav and Hurwitz (1996) found that heart percent of broiler birds exposed to 36°C was significantly lower compared to the unexposed birds.

Ain Baziz *et al.* (1996) reported that when broiler chicks were reared at two temperatures, 32 and 22°C, heat exposed birds had higher leg proportion and dressing percentage, and lower breast proportion. Abdominal fat and intramuscular fat also increased. They concluded that the effect of heat exposure on fat deposition could be related to the age of birds, and the temperature regimen, whether cyclic or constant.

Mendes *et al*. (1997) found that birds reared under heat stress environment had significantly higher dressing percentage, leg yield and abdominal fat, while breast meat yield was lower comparing to the birds grown under thermoneutral conditions.

Ababneh (2001) studied the effect of high environmental temperatures on chicks` carcass characteristics. He reared broilers at constant ambient temperatures of 26, 30, 34, and 38°C, and reported that birds under those high ambient temperatures had no significant differences in liver, heart and gizzard percentages.

Smith (1993b) conducted a study to examine the effects of cyclic high environmental temperature during the growing period on carcass composition. Broilers were reared from 23 to 49 days of age at either 23.9°C constant temperature or 23.9-35°C cyclic temperature. Birds in the hot environment had higher protein and less fat content of thighs and drumsticks, while breast protein was not affected compared to those reared under thermoneutral conditions. He concluded that carcass composition is altered under heat stress.

Geraert *et al*. (1996) studied the effect of chronic heat exposure (constant 32°C) on growth and body composition of broilers. They cited that heat-stressed birds had a decrease in protein and an increase in lipid content of the body, while body ash content was not affected compared to those kept under 22°C.

2.2. EFFECT OF HEAT STRESS ON BROILERS PHYSIOLOGY

2.2.1. RECTAL TEMPERATURE

Elhadi and Sykes (1982) exposed laying hens to temperatures of 32, 35, 38 and 41°C. They found no changes in body temperature at 32°C, while at 35°C, body temperature increased to 41.9°C, at 38°C body temperature increased to 42.3°C, and at 41°C it increased within 75 minutes to 44°C. Yahav and Hurwitz (1996) found that rectal temperature of 4 weeks old broiler birds exposed to 36°C was 41.3°C which was significantly higher than birds reared at 22°C by 0.6°C. The following week, all the birds were again exposed to 36°C. Rectal temperature rose significantly to 42.01°C compared to 40.63°C of broilers grown at 22°C.

Abu-Dieyah (2006) studied the effect of heat stress on physiology of broiler chickens reared under two constant ambient temperatures (20±1°C vs. 35±1°C). His findings showed that rectal temperature of the birds reared at 35°C was higher than those of the birds reared at 20°C.

2.2.2. RESPIRATORY RATE

Panting is one of the main responses that broilers show during heat exposure, as they have no sweat glands. Panting is the physiological mechanism that reduces the effect of heat stress by preventing the rise in body temperature when environmental temperature is above the thermoneutral zone (Kamal, 1975). Under high environmental temperatures, evaporative cooling is the only way by which heat can be lost (Siegel, 1969). Hens start panting at an ambient temperature of 29°C or after 60 minutes of exposure to 37°C and 45% relative humidity (Wang *et al.,* 1989).

Abu-Dieyah (1997) studied the respiratory rate of broilers under different ambient temperatures of 25, 30 and 35, and 24-28°C. He found that the respiratory rate of birds kept at 35°C was significantly higher than birds at the other temperatures, it was 136 breaths/minute compared to 121, 44 and 45 breaths/minute at 30, 25 and 24-28°C, respectively. Abu-Dieyah (2006) also studied the effect of heat stress on physiology of broiler chickens reared under two constant ambient temperatures (20±1°C vs. 35±1°C). He found that respiratory rate of the birds reared at 35°C was higher than that of the birds reared at 20°C. The increase in respiratory rate in heat stressed broilers is accompanied by a decrease in the level of blood carbon dioxide, causing high blood pH, which is generally called alkalosis (Elhadi and Sykes, 1982).

2.3. EFFECT OF DIETARY METABOLIZABLE ENERGY LEVEL ON BROILERS PERFORMANCE

Fisher and Wilson (1974) made a quantitative analysis of published data and showed that when dietary ME in broiler feeds was varied with the energy: protein ratio held constant, the resulting responses to increasing dietary ME were decline in feed intake, increase in ME intake, increase in weight gain, improvement in feed conversion ratio and increase in fat content of the carcass.

Sinurat and Balnave (1985) found that increasing dietary ME at a particular amino acid: ME ratios significantly improved growth and feed utilization of broilers kept at cyclic moderate (18-26°C) and cyclic high (25-35°C) ambient temperatures during the finisher period (from 22-45 days of age). Also, the increase in feed intake and growth rate occurred in the hot environment when dietary ME was increased and the amino acid:ME ratio was reduced.

Holsheimer and Veerkamp (1992) fed broilers diets with different protein and lysine levels, at ME levels of 3200 or 2880 kcal/kg. They found that weight gain and feed conversion ratio were better with the high energy diets at 6, 7, and 8 weeks of age.

Veldkamp *et al*., (2005) studied the effects of ambient temperature (18 vs. 28°C), different dietary metabolizable energy levels (90, 100, and 110%) and dietary lysine level (105 vs. 120%) of NRC (1994) recommendations, and their interactions on feed intake, weight gain, feed conversion ratio, and carcass yield of male turkeys from 29 to 140 d of age. Feed intake decreased linearly as energy increased and was more pronounced at low compared with high temperature. Weight gain decreased and feed conversion ratio improved as energy level increased. The highest energy content resulted in lower cold carcass, and breast meat yield, higher thigh and drum yield than the lowest energy.

Nawaz *et al*. (2006) conducted an experiment to investigate the effect of different levels of energy and protein on broilers performance. Six broiler starter diets with two levels of ME (2800 and 3000 kcal/kg) and three levels of crude protein (20, 21 and 22%) were offered from hatching to 28 days of age. Similarly, six broiler finisher diets with two levels of ME (3000 and 3200 kcal/kg) and three levels of crude protein (16, 17 and 18%, and 18, 19 and 20%, respectively) were offered from 29-42 days of

age. Feed intake and weight gain were higher with the low ME, while there was no effect of ME on carcass characteristics.

Zaman, *et al*., (2008) studied the effect of different energy and protein levels on broilers performance during June to August, considered as the hot and humid months in Pakistan. During the first week of the experiment, the house temperature was maintained at 35°C and after that daily cyclic temperature was followed. They used two levels of ME (12.13 and 12.55 MJ/kg), and three levels of dietary crude protein (19, 21 and 23%). They found that increasing ME significantly increased weight gain, abdominal fat, liver weights, fat and protein contents of the carcass, whereas carcass dry matter was reduced. Metabolizable energy had no effect on carcass, breast, heart and gizzard weights.

Rabie *et al*. (2010) conducted a study on broilers. They fed the birds two diets (starter and grower) with different energy levels and concluded that decreasing dietary ME level in both starter and grower periods from 3100 to 2700 kcal/kg decreased abdominal fat, but had no significant effect on body weight, weight gain, feed intake and some blood parameters.

Some researchers found that broilers did not respond to increasing energy when reared in normal (Leeson *et al*., 1991) or hot environment (Bacon *et al*., 1981). Increased mortality rate has been noticed in heat stressed birds when dietary energy was increased (Teeter and Belay, 1996). Moreover, dietary energy level affects broilers physiology, rectal temperature increased with high ME level in the diet (Sykes and Fatafitah, 1980; Sykes, 1983; Sinurat and Balnave, 1985).

2.4. EFFECT OF DIETARY FAT SUPPLEMENTATION ON BROILERS PERFORMANCE

Dale and Fuller (1979) conducted a study on broilers, they used four experimental diets with dietary fat ranging from 2.5 to 11.9%, in an attempet to reduce

the effects of heat stress on broilers by lowering the heat increment of the diet. The percent of energy derived from fat was increased by replacing corn starch with fat, calorie for calorie, which increased diet density. Diet A contained 18% corn starch as replacable carbohydrates (CHO). In diet B poultry fat replaced corn starch, calorie for calorie, which increased diet density by 11% and increased fat calories to reach 33.2% of total dietary calories. In an attempt to reduce heat increment, further, the level of protein in diet C was lowered, while maintaining approximately the same percentage of fat as in diet B. In order to maintain recommended levels of essential amino acids, supplements of L-arginine, L-lysine, and DL-Methionine were added. Diet D also contained a high percentage of fat calories (33.6%), but the density was restored to that of diet A by the addition of a non-nutritive filler. Experimental diets were fed to male broiler chicks from 4-7 weeks of age in hot (31.1±2°C) vs. cool (20±2°C) controlled temperature chambers. They found that ME intake was increased when fat calories replaced CHO calories. In the high fat treatments, chicks weight gain was higher than that of the high CHO control group. This increase was similar at both temperatures, indicating that the beneficial effect of dietary fat was independent of temperature. Metabolizable energy intake was increased in all high fat (high density) treatments. They concluded that dietary energy and probably protein as well, would be utilized more efficiently with the high density diets.

Dale and Fuller (1980) subjected broilers from 5-7 weeks of age to a constant cool (14±1°C) or hot (31±1°C) environment and fed diets varying in fat levels (2.25, 2.52, 8 and 10.77%), energy, and nutrient density. They reported that in both environments chicks fed high fat or high fat-high density diets gained more weight and had a better feed conversion ratio than those fed diets low in fat, and when temperatures were cycled diurnally (cool, 14-22 °C, and hot, 22-33 °C) as would occur under natural

conditions, the growth depression due to heat stress was less in chickens fed the diets high in fat. Sinurat and Balnave (1985) studied the effect of dietary supplemental fat (0-10.5%) on broilers kept at cyclic moderate (18-26°C) and cyclic high (25-35°C) ambient temperatures. They found that fat supplementation had no beneficial effect on performance at high temperatures. Leeson *et al.* (1996) reported that feeding broiler chicks diets of 2700 to 3300 kcal ME/kg (by supplementing with dietary fat ranging from 1.15 to 8.65%), had no effect on growth rate or energy intake but linearly increased feed intake. Layers on 4% supplemented fat diets had a higher weight gain, less daily feed intake, produced heavier eggs, and had feed conversion ratio better than those on 0% added dietary fat (Usayran *et al*., 2001).

Dietary supplemental fat improves energy efficiency of a diet fed during hot weather in 3 ways: First, dietary fat has 2.25 times more energy per unit of its weight than that of CHO or protein, thus, fat can be used to increase flexibility of feed formulation by allowing more inclusion possibilities for other crucial nutrients and can be considered as a concentrated source of energy. Second, fat has the lowest heat increment as compared to CHO or protein (Daghir, 1995). Digestion and metabolism of dietary fat when absorbed and used for growth generates less body heat increment (5-10% of ME) than CHO (10-15% of ME) and protein (30% of ME). The reduction of metabolic heat from dietary fat compared with other forms of energy increased the performance of broilers fed high-energy diets at high ambient temperature (Reece and McNaughton, 1982). Third, the rate of food passage (transit time) is reduced by dietary fat, thus, diet will be more thoroughly digested and absorbed (Mateos and Sell, 1981; Mateos *et al*., 1982). Therefore, dietary fat produces an "extra caloric effect" characterized by enhanced energy utilization (Fisher and Wilson, 1974).

2.5. EFFECT OF FEED PELLETING ON BROILERS PERFORMANCE

Reece and McNaughton (1982) found that pelleting improved feed conversion ratio by 1.5% and increased body weight by 2.2%. Choi *et al*. (1986) fed broilers from 4 to 8 weeks of age on mash or pelleted diets, and found that pelleting the finisher diet significantly improved weight gain and feed intake, and reduced weights of the digestive tract and the gizzard at 8 weeks of age compared to those fed the mash diet.

Leeson *et al*. (1999) investigated the effects of diets of varying nutrient density fed to broilers as mash or as pellets. Broilers fed pellets had higher mortality (15.3 vs. 3.93%), growth rate (4.13 vs. 3.68 kg at 70 days), feed efficiency, feed intake and breast meat yield, as well as more abdominal fat compared to those fed mash.

Quentin *et al*. (2004) studied the effect of feeding fast and slow-growing broilers mash or pelleted diets from 15 to 35 days of age. They reported that the fast-growing broilers fed pelleted feed had a 19% higher body weight, a 12% higher feed intake, and a 12% lower (improved) feed conversion ratio than those fed mash. No effect of feed form on mortality was detected. Also, feed form had no significant effect on feed intake, weight gain, and body weight of slow-growing chickens.

Different studies showed variation in results between researchers, which might be due to: First, different quality of pellets used in the different studies or the use of different production procedures. Second, use of different species (chickens or turkeys) and different ages. Third, comparison of the effect of pelleting in feeds with variable energy levels due to differences in fat supplementation and fiber-containing ingredients. Several mechanisms have been suggested to explain the effects of pelleting on performance variables. The decrease in diet volume and the large particle size were considered to facilitate feed or energy consumption and hence promote growth (Plavnik *et al*., 1997).

3. MATERIALS AND METHODS

The experiment was conducted from March 3rd. till April 14th. 2010.

3.1. EXPERIMENTAL ROOMS

3.1.1. ENVIRONMENTALLY-CONTROLLED HOUSE

An environmentally-controlled poultry house consists of 6 identical rooms located in the poultry farm at the University of Jordan Station for Dry Land Research located at Al-Muwaqqar east of Amman. Each room measures 28.5 m^2, three of which were divided by a wire mesh into 6 identical pens with an area of 2 m^2 to be used in this study. The pens were equipped with separate feeders and automatic-cone drinkers. Rooms were supplied individually with thermostatically controlled electrical heaters. Temperature was controlled inside the house through electronic control panel boxes fixed outside the rooms. Electric fans (for air circulation) and exhausting fans were provided.

3.1.2. OPEN-SIDED POULTRY HOUSE

The open-sided poultry house was divided using a wire mesh into 18 identical pens (each measures 2 m^2) equipped with separate feeders and automatic-cone drinkers.

3.1.3. ENVIRONMENTALLY-CONTROLLED CHAMBERS

Two controlled environmentally-controlled chambers were used for heat tolerance test, they are located in the environmental physiology lab, Animal Production Department, Faculty of Agriculture at the campus of the University of Jordan. Each chamber was equipped with thermostatically controlled electric heaters and an electric fan for air circulation. Ambient temperature can be controlled to the accuracy of ±1°C.

3.2. EXPERIMENTAL BIRDS

A total of 1100 straight-run one-day-old broiler chicks of Lohmann strain were used in this experiment. Chicks were brought from a local commercial hatchery,

weighed on arrival, and raised from day 1 to 28 as one group at the open-sided house. At 28 days age, 900 birds were randomly divided into two groups of 450-bird each (A&B). Each group was assigned to 6 experimental dietary treatments (75 birds each), with 3 replicates of 25 birds each.

3.2.1. GROUP A:

The birds were kept at the open-sided house, randomly distributed into 18 replicates (25 chicks each), and given the six different dietary treatments under natural ambient temperature.

3.2.2. GROUP B:

The birds were transferred from the open-sided poultry house to the controlled environmental rooms, fed the same dietary treatments and distributed as in group A, but under artificially induced heat stress (35±1).

3.3. EXPERIMENTAL AMBIENT TEMPERATURES

Room temperature was maintained at 35°C during the first week and reduced by 1°C per day thereafter, untill maintained at 21°C. During the experimental (finisher) period, ambient temperature at the open-sided house ranged from 17-25°C (variable-natural temperature), while maintained constant at 35±1°C in the controlled rooms.

3.4. EXPERIMENTAL DIETS

Diets ingredients and chemical composition are shown in table 1. Birds were fed commercial pelleted starter and grower diets (two weeks each). On day 28, they were given three fat levels (2, 4 and 6%) as the supplemental energy source, and two feed forms; mash and pellets, to form six different isonitrogenous dietary treatments (table 1), which were randomly assigned to the birds. Plant dry fat (Polyfat) is manufactured by Norel-Misr, Egypt, made from dried palm oil, Chemical composition of this fat is shown in table 2. It was used in the finisher diets instead of soybean oil that has been

used in the starter and grower diets. Phytase was added on top, not included in the diets calculation.

3.5. MANAGEMENT PRACTICES

All management practices for both groups (including vaccination) were in accordance with the recommended standard commercial guide program for the strain used. Birds were reared on wood-shavings litter, feed and water were provided *ad libitum* throughout the experimental period. A (23L: 1D) lighting regimen was provided.

3.6. PARAMETERS MEASURED:

3.6.1. ON DAILY BASIS:

Mortality and rooms temperature were recorded daily throughout the experiment.

RECTAL TEMPERATURE AND RESPIRATORY RATE:

Rectal temperature and respiratory rate were recorded at the same time everyday during the period of exposing birds to heat stress conditions (experimental period). Three birds from each replicate within a treatment were selected randomly, marked and used for these measurements. Rectal temperature was measured by inserting a rectal probe of a digital thermometer 5 cm into the cloaca. Respiratory rate was counted using a stopwatch by the number of inhalation-exhalation per minute.

3.6.2. ON WEEKLY BASIS:

Feed intake, body weight, weight gain and feed conversion ratio were measured at the end of every week. Feed intake was measured from differences in weight between known weight of feed supplied and feed left in each pen at the end of the week. Weight gain was measured as the difference in body weight between the end and the start of the

Table 1. Ingredients and chemical composition of the experimental diets.

Ingredients	Starter (0-14 d)	Grower (15-27 d)	Finisher (28-42 d) 2% fat	Finisher (28-42 d) 4% fat	Finisher (28-42 d) 6% fat
	(%)				
Corn	58.48	62.21	68.3	66.8	65.2
Soyabean Meal (48%CP)	35.65	31	26	26	26
Soya Oil	1.7	2.61	0	0	0
Plant Dry Fat	0	0	2	4	6
Limestone	1.4	1.4	1	0.5	0.1
DCP	1.4	1.4	1.4	1.4	1.4
Salt	0.41	0.41	0.42	0.42	0.42
DL-Methionine	0.2	0.2	0.2	0.2	0.2
L-Lysine	0.16	0.17	0.18	0.18	0.18
Coccidiostat	0.1	0.1	0	0	0
Vitamin Premix[1]	0.1	0.1	0.1	0.1	0.1
Mineral Premix[2]	0.1	0.1	0.1	0.1	0.1
Choline Chloride	0.1	0.1	0.1	0.1	0.1
Antioxidant	0.1	0.1	0.1	0.1	0.1
Anti-Fungal	0.1	0.1	0.1	0.1	0.1
Nutrient composition					
Analyzed					
CP[3] %	22.1	20.2	18.3	18.2	18.0
EE[3] %	4.6	5.2	4.9	6.6	8.2
Calculated					
ME (kcal/kg)	2990	3080	3030	3130	3230
Ca %	0.9	0.9	0.9	0.9	0.9
NPP[3] %	0.4	0.4	0.4	0.4	0.4
Na %	0.2	0.2	0.2	0.2	0.2
Methionine %	0.5	0.5	0.5	0.5	0.5
TSAA %	0.9	0.9	0.8	0.8	0.8
Lysine %	1.3	1.2	1.1	1.1	1.1
Tryptophan %	0.3	0.3	0.2	0.2	0.2
Threonine %	0.8	0.8	0.7	0.7	0.7

[1]Vitamin premix provided per kilogram of diet: vitamin A, 14000 IU; vitamin D_3, 5000 IU; vitamin E 50 mg; vitamin B_1, 3 mg; vitamin B_2, 8 mg; vitamin B_6, 4 mg; vitamin B_{12}, 16 mg; Biotine, 0.15 mg; Niacine, 70 mg; Folic Acid, 2 mg; DL Ca. pantothenate, 20 mg.
[2] Trace mineral premix provided per kilogram of diet: Iron, 80mg; Zinc, 80 mg; Copper, 8 mg; Iodine, 1 mg; Selenium, 0.15 mg.
[3]CP (crude protein), EE (ether extract), NPP (nonphytate phosphorus).

Table 2. Composition of plant dry fat (on as-fed basis).

Composition / Analysis	(%)
Crude fat	84
Ash	12.4
Calcium	8
MIU[1]	3.585
Anti-oxidant	0.015

[1]**MIU (moisture, insolubles and unsaponifiables).**
Source: Norel-Misr company, Egypt.

week. Feed conversion ratio was calculated by dividing feed intake over weight gain, and corrected for mortality.

3.6.3. AT THE END OF THE EXPERIMENTAL PERIOD:

Birds response was measured in terms of cumulative body weight, weight gain, feed intake, feed conversion ratio and mortality. Carcass traits and some blood parameters were also measured. Two birds from each replicate were randomly selected (after 12 hours of feed deprivation), slaughtered, scalded, feathers mechanically plucked in a rotary drum picker and eviscerated. Feet, shanks and heads were removed and carcasses were immediately weighed to obtain hot carcass weight without giblets. Giblets (liver, heart and gizzard) were removed, weighed, and expressed as a percentage of live body weight. After that, carcasses were tagged, chilled in ice-water for 30 minutes, individually packed in polyethylene bags and kept in refrigerator for 12 hours, after which they were weighed to obtain cold carcass weight, abdominal fat was removed and carcasses were dissected into different parts (neck, back, wings, legs and breast). Cuts and abdominal fat were weighed and expressed as a percentage of cold carcass weight to determine parts yield, then the cuts were put in polyethylene bags and stored in freezer for further analysis. Blood samples were collected from jugular vein at slaughter into plain tubes, centrifuged at 3000 RPM for 15 minutes to obtain serum, and stored at -20°C, to be analyzed for the main constituents that were expected to be

affected by heat stress and/or the other treatments. Parameters analyzed were cholesterol, high density lipoprotein (HDL), low density lipoprotein (LDL), and triglycerides using (Vitros 250, France) with specialized kits (Ortho-Clinical Diagnostics) at a private medical lab.

3.6.4 HEAT TOLERANCE TEST:

Birds from group B were subjected to heat tolerance test. Two randomly selected birds from each replicate within a treatment were placed in individual cages without feed or water and exposed to a temperature of 42±1°C for 4 hours or until rectal temperature reached 45°C or death occured. Birds rectal temperature was recorded at the beginning of the test (zero time), then at hourly intervals, or more frequently if approached 45°C. The rate of increase of rectal temperature (RITr) during the test was calculated from the increase in rectal temperature per hour of heat exposure (by dividing the change of rectal temperature (°C) on the time period (hours) spent at 42±1°C). This parameter was used by Sykes and Alfataftah (1986) as an indicator of heat tolerance. Rate of increase of rectal temperature was used to compare the heat tolerance when the duration of heat exposure was not similar for different birds. The test was conducted at 28 days of age (beginning of experiment) and at 42 days of age (end of experiment) to find out the changes in heat tolerance.

3.7 CHEMICAL (PROXIMATE) ANALYSIS

Feed and meat chemical composition analysis was conducted at the laboratory of Animal Production Department/ Faculty of Agriculture/ University of Jordan, according to the recommendations of AOAC (2000).

Randomized samples of the diets were collected and ground by POLYMIX grinder (PX-MFC 90 D, KINEMATICA AG, Switzerland) through 1mm screen, dried

in a forced air oven for six hours at 105°C to determine their dry matter contenet, then samples were analyzed for crude protein, crude fiber, ether extract and ash contents.

Meat samples (from breast and leg) were minced to a finely divided homogenous paste by passing them through a grinder fitted with a fine screen, then dried in two steps: First, in a forced air oven for 72 hours at 60°C, followed by grinding using POLYMIX grinder (PX-MFC 90 D, KINEMATICA AG, Switzerland) through 1mm screen. Next, dried for six hours at 105°C. Thereafter, samples were analyzed for crude protein, ether extract and ash contents.

Crude protein was determined following the macro-Kjeldal method of nitrogen determination. Samples were digested with sulfuric acid at the boiling point of the same acid using (DK heating digester, VELP SCIENTIFICA, Italy), then distilled (Vapodest 30, Gerhardt, Germany), and titrated to determine their nitrogen content, which was multiplied by 6.25 to determine crude protein content. Ash was calculated by complete combustion (for six hours at 600°C) using muffle furnace (N7/H, Naber, Industrieofenbau, D-2804 Lilienthal/ Bremen, Germany). Ether extract was determined with petroleum ether (SER 148 Solvent Extractor, VELP SCIENTIFICA, Italy). Extraction included three steps; immersion for 50 minutes, washing for 80 minutes and recovery for 30 minutes. Prior to extraction, feed samples containing dry fat were prepared by acid hydrolysis method, one gram of the sample was treated with 50 ml of 4N HCL, boiled under reflux for 1 hour, filtered with filter paper, then the precipitate was washed with distilled water 3 times, dried with filter paper in an oven at 100°C for 6 hours. Crude fiber was determined by ANKOM 220 FIBER ANALYZER (ANKOM TECHNOLOGY, USA). Samples were digested with H_2SO_4 (1.25%), then with KOH (1.25%), each steps at 110°C for 45 minutes.

3.8 MEAT QUALITY CHARACTERISTICS

Meat quality measurements were carried out at the laboratories of Animal Production Department/ Faculty of Agriculture/ Jordan University of Science and Technology.

3.8.1 pH AND COLOUR MEASUREMENTS:

The pH values were determined by using the iodoacetate method (Jeacocke, 1977; Sams and Janky, 1986). Around 1-1.5 g of raw muscles were put into plastic test tubes containing 10 ml of neutralized 5 mM iodoacetate reagent and 150 mM KCL and homogenized using homogenizer (Ultra-Turrax) T8 (IKA Labortechnik, Janke & Kunkal GmbH & Co., Germany). Before recording the pH, values of the solutions were standardized on a pH meter (pH spear, model 35634-40, Eurotech Instruments, Malaysia). The pH was measured at three points on the cranial area of the pectoral superficial muscle (*Major Pectoralis*) at about 5 cm from the sternum line.

Colour measurements were taken on the same area as pH for each sample using a coluormeter (12 MM Aperture U 59730-30, Cole-Parameter International Inc, Pittsford, NY, USA). Three measurements were taken at each point on the medial portion of the pectoralis muscle. Colours of each sample were expressed in terms of values for lightness (L*), redness (a*) and yellowness (b*) of the meat.

3.8.2 WATER HOLDING CAPACITY:

Water Holding Capacity (WHC) was measured using the method described by Grau and Hamm (1953) and modified by Safiudo *et al*. (1986). Samples of an initial weight of 5 g of raw meat were used (one sample per replication). Each sample was cut into smaller pieces and covered with two filter papers (qualitative, 185 mm circles, fine crystalline retention) and two thin plates of quartz material, then pressed with weight of 2500 g for five minutes. The meat samples were then removed from filter paper and

their weight was recorded (final weight). Water holding capacity was calculated as the difference between initial and final weight divided by the initial sample weight and expressed as a percentage.

3.8.3 COOKING LOSS AND SHEAR FORCE MEASUREMENTS:

Meat samples of about 250 g were weighed and put in well sealed bags without air in a freezer at -20°C. Breasts were then thawed, taken out of plastic bags to determine loss in weight. The breasts were put individually in sealed plastic bags, cooked in thermostatically controlled water bath at 85°C for 25 minutes to achieve the maximum internal temperature of 80°C. Samples were then removed and put under running cold water to cool down for 45 min, then well dried and weighed to determine the cooking loss. Cooking loss was reported as weight loss during cooking divided by fresh sample weight and expressed as a percentage. The cooked pieces of meat were cut to obtain 6 cores (20×13×13 mm) on each breast sample (6-8 carrots) using cylindrical metal that measures 1.25 cm in diameter to determine shear force of meat according to Bratcher *et al*. (2005), (Warner-Bratzler Meat Shear Apparatus/INSTRON, G-R manufacturing Co., 1317 Collins LN, Manhattan, Kansas, 66502, USA). This apparatus measures the maximum strength in kg/cm^2.

3.9. STATISTICAL ANALYSES

Completely randomized design (CRD) was used. Two ambient temperatures, three dietary fat levels and two feed forms were analyzed as (2×3×2) factorial arrangement using GLM procedure of SAS (2004). Means of significant ($P<0.05$) effects were compared using Fisher protected LSD.

4. RESULTS AND DISCUSSION

4.1. PERFORMANCE

4. 1. 1. BODY WEIGHT

Means ± SEM of body weight of broilers are shown in table 3. Under both temperatures, different dietary fat percentages and feed pelleting did not improve the final body weight. However, under natural temperature, the highest final body weight value (2500 g) resulted from the pelleted 4% fat diet, while under heat stress, the pelleted 2% fat diet resulted in the highest body weight (2173 g). Jensen *et al.* (1962) reported that body weight improved with feed pelleting, due to the reduction in the energy and time required for eating a pelleted diet. Also, McNaughton and Reece (1984) found that pelleting increased body weight by 2.2%. That improvement in body weight with feed pelleting was not observed in the current study.

The differences in final body weight between the two different temperatures were significant ($P<0.05$), natural temperature gave better results. That indicates the negative effect of high ambient temperature on body weight, which could be attributed to decreased feed intake of birds attempting to minimize the amount of body heat generated from digestion and energy metabolism (Ferket, 1995). These results are in agreement with Hacina *et al*. (1996), who found that body weight of broilers reared at 32°C was 47% less than that of broilers reared at 22°C.

4.1.2. WEIGHT GAIN

Means ± SEM of weight gain of broilers are shown in table 4. There was no significant effect for dietary fat percentage or feed pelleting on cumulative weight gain of birds under both temperatures (natural or heat stress). Jensen *et al*. (1962) reported that the number of meals consumed per day was about the same for pelleted and mash feeds, but the duration of each meal was reduced three-fold in chickens when pellets were fed.

Table 3. Least square means (±SEM) of body weight of broilers (gram) as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 °C)		Heat stress (35±1 °C)	
	Age (days)		Age (days)	
	28-35	35-42	28-35	35-42
2% Fat				
Mash	$1888 \pm 52^{B\text{-}a}$	$2313 \pm 52^{B\text{-}a}$	$1736 \pm 62^{AB\text{-}b}$	$1980 \pm 62^{A\text{-}b}$
Pelleted	$2131 \pm 52^{A\text{-}a}$	$2413 \pm 52^{AB\text{-}a}$	$1899 \pm 62^{A\text{-}b}$	$2173 \pm 62^{A\text{-}b}$
4% Fat				
Mash	$1903 \pm 52^{BC\text{-}a}$	$2353 \pm 52^{AB\text{-}a}$	$1716 \pm 62^{B\text{-}b}$	$1913 \pm 62^{A\text{-}b}$
Pelleted	$2144 \pm 52^{A\text{-}a}$	$2500 \pm 52^{A\text{-}a}$	$1888 \pm 62^{AB\text{-}b}$	$2140 \pm 62^{A\text{-}b}$
6% Fat				
Mash	$1906 \pm 52^{BC\text{-}a}$	$2313 \pm 52^{B\text{-}a}$	$1776 \pm 62^{AB\text{-}b}$	$2047 \pm 62^{A\text{-}b}$
Pelleted	$2044 \pm 52^{AC\text{-}a}$	$2427 \pm 52^{AB\text{-}a}$	$1855 \pm 62^{AB\text{-}b}$	$2070 \pm 62^{A\text{-}b}$

A-C Means in the same column with no common superscripts are significantly different ($P<0.05$).
a-b Means in the same row (within the same age) with no common superscripts are significantly different ($P<0.05$).

Table 4. Least square means (±SEM) of weight gain of broilers (gram) as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)			Heat stress (35±1 ^{o}C)		
	Age (days)			Age (days)		
	28-35	35-42	28-42	28-35	35-42	28-42
2% Fat						
Mash	415±50^{CD-a}	425±50^{AC-a}	840±77^{A-a}	272±50^{BC-b}	244±50^{A-b}	516±77^{AC-b}
Pelleted	653±50^{A-a}	283±50^{BC-a}	936±77^{A-a}	419±50^{A-b}	275±50^{A-a}	693±77^{A-b}
4% Fat						
Mash	433±50^{BD-a}	451±50^{A-a}	884±77^{A-a}	273±50^{BC-b}	197±50^{A-b}	471±77^{BC-b}
Pelleted	645±50^{A-a}	356±50^{AC-a}	1001±77^{A-a}	394±50^{AC-b}	252±50^{A-a}	647±77^{AC-b}
6% Fat						
Mash	397±50^{CD-a}	407±50^{AC-a}	804±77^{A-a}	269±50^{BC-a}	271±50^{A-a}	540±77^{AC-b}
Pelleted	532±50^{B-a}	383±50^{AC-a}	915±77^{A-a}	372±50^{AC-b}	215±50^{A-b}	587±77^{AC-b}

A-D Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same age) with no common superscripts are significantly different (P<0.05).

This means that offering pelleted feed to broilers can result in a 67% reduction in the energy required for eating. Choi *et al*. (1986) fed broilers 4-8 weeks of age on mash or pelleted diets, and found that pelleting the finisher diet significantly improved weight gain. Dietary fat level did not affect weight gain under both temperatures. Similarly, Sinurat and Balnave (1985) kept broilers during the finisher period (22-45 days of age) under high ambient temperatures (25-35 °C), fed diets varying in fat (0-10.5%), and found that fat failed to improve broiler performance under high ambient temperatures. In contrary to our results, Dale and Fuller (1980) subjected broilers 5-7 weeks of age to a constant cool (14±1°C) or hot (31±1°C) environment, fed diets varying in fat levels. They reported that in both environments, high fat diets increased broilers weight gain compared to low fat diets.

Heat stress decreased ($P<0.05$) weight gain compared to natural temperature. That could be attributed to temperature *per se* (Hacina *et al*., 1996), impaired metabolism (Farrel and Swain, 1978), and reduced feed intake. These results are in harmony with previous findings (Hurwitz *et al*., 1980; Geraert *et al*., 1996; Yahav *et al*., 1996).

4.1.3. FEED INTAKE

Means ± SEM of feed intake of broilers are shown in table 5. Under both temperatures, there was no significant effect for dietary fat or feed form on cumulative feed intake, except a significant effect for feed form under heat stress, where pelleted feed resulted in higher ($P<0.05$) feed intake compared to mash at the 2% fat diet**.** Leeson *et al*. (1996) reported that feeding broiler chicks diets with dietary fat ranging from 1.15 to 8.65% linearly increased feed intake. The decrease in diet volume and the large particle size with feed pelleting were considered to facilitate feed or energy consumption and hence promote growth (Plavnik *et al*., 1997), because of the reduction

Table 5. Least square means (±SEM) of feed intake (gram) of broilers as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)			Heat stress (35±1 ^{o}C)		
	Age (days)			Age (days)		
	28-35	35-42	28-42	28-35	35-42	28-42
2% Fat						
Mash	$997 \pm 54^{BC-a}$	$1088 \pm 133^{A-a}$	$2085 \pm 187^{A-a}$	$649 \pm 54^{BD-b}$	$654 \pm 133^{A-b}$	$1304 \pm 187^{BC-b}$
Pelleted	$1336 \pm 54^{A-a}$	$827 \pm 133^{A-a}$	$2163 \pm 187^{A-a}$	$1143 \pm 54^{A-a}$	$730 \pm 133^{A-a}$	$1873 \pm 187^{A-a}$
4% Fat						
Mash	$1036 \pm 54^{B-a}$	$1126 \pm 133^{A-a}$	$2162 \pm 187^{A-a}$	$749 \pm 54^{BC-a}$	$548 \pm 133^{A-b}$	$1297 \pm 187^{BC-b}$
Pelleted	$1316 \pm 54^{A-a}$	$1007 \pm 133^{A-a}$	$2323 \pm 187^{A-a}$	$1032 \pm 54^{AC-a}$	$640 \pm 133^{A-b}$	$1672 \pm 187^{AC-b}$
6% Fat						
Mash	$875 \pm 54^{C-a}$	$1088 \pm 133^{A-a}$	$1963 \pm 187^{A-a}$	$739 \pm 54^{BC-a}$	$735 \pm 133^{A-b}$	$1474 \pm 187^{AC-b}$
Pelleted	$1233 \pm 54^{A-a}$	$1073 \pm 133^{A-a}$	$2305 \pm 187^{A-a}$	$924 \pm 54^{ACD-b}$	$654 \pm 133^{A-b}$	$1578 \pm 187^{AC-b}$

A-D Means in the same column with no common superscripts are significantly different ($P<0.05$).
a-b Means in the same row (within the same age) with no common superscripts are significantly different ($P<0.05$).

in the time spent in feed consumption. However, that improvement in feed intake due to pelleted feed was not oserved in the current study.

The differences in cumulative feed intake between the two different temperatures were significant ($P<0.05$), in an overall view, natural temperature gave better results in most cases, except a nonsignificant difference observed when pelleted 2% fat diet was fed. That indicates that the pelleted 2% fat diet improved birds feed intake under heat stress. The depression in feed intake is one of the first bird`s responses in order to reduce metabolic heat production under heat stress conditions, which consequently leads to the depression of the other performance parameters discussed previously. Yahav *et al*. (1996) reported a reduction in feed intake by 10, 20, and 46% when ambient temperature increased from 20°C to 25, 30, and 35°C, respectively.

4.1.4. FEED CONVERSION RATIO

Means ± SEM of feed conversion ratio of broilers are shown in table 6. There was no significant effect for dietary fat percentage or feed form on the overall feed conversion ratio under both temperatures. Dale and Fuller (1980) fed broilers diets varying in fat levels (2.25, 2.52, 8 and 10.77%), and found that feed coversion ratio was better with the high fat diets under both, the constant cool (14±1°C) and hot (31±1°C) environments. However, that improvement in feed conversion ratio was not observed in this study, as the range of fat percentage did not seem wide enough to cause a significant effect on this specific parameter. Moreover, Choi *et al*., (1986) and Leeson *et al*., (1999) reported that feed conversion ratio improved with pelleted feed, which also was not observed in this study.

Higher ($P<0.05$) feed conversion ratio resulted from heat stress compared to natural temperature. But that difference was not observed when mash 2% fat and pelleted 6% fat diets were fed. Hurwitz *et al*. (1980) reported that the feed efficiency

Table 6. Least square means (±SEM) of feed conversion ratio (g feed:g weight gain) of broilers as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^oC)			Heat stress (35±1 ^oC)		
	Age (days)			Age (days)		
	28-35	35-42	28-42	28-35	35-42	28-42
2% Fat						
Mash	$2.40±0.14^{A-a}$	$2.53±0.14^{AC-a}$	$2.49±0.08^{A-a}$	$2.37±0.14^{BC-a}$	$2.67±0.14^{BC-a}$	$2.55±0.08^{A-a}$
Pelleted	$2.00±0.14^{A-b}$	$2.90±0.14^{A-a}$	$2.31±0.08^{A-b}$	$2.67±0.14^{AC-a}$	$2.63±0.14^{BC-a}$	$2.70±0.08^{A-a}$
4% Fat						
Mash	$2.33±0.14^{A-b}$	$2.50±0.14^{BC-a}$	$2.45±0.08^{A-b}$	$2.70±0.14^{A-a}$	$2.73±0.14^{AC-a}$	$2.76±0.08^{A-a}$
Pelleted	$2.03±0.14^{A-b}$	$2.80±0.14^{AC-a}$	$2.32±0.08^{A-b}$	$2.57±0.14^{AC-a}$	$2.57±0.14^{BC-a}$	$2.60±0.08^{A-a}$
6% Fat						
Mash	$2.20±0.14^{A-b}$	$2.63±0.14^{AC-a}$	$2.45±0.08^{A-b}$	$2.67±0.14^{AC-a}$	$2.70±0.14^{AC-a}$	$2.75±0.08^{A-a}$
Pelleted	$2.33±0.14^{A-b}$	$2.77±0.14^{AC-a}$	$2.54±0.08^{A-a}$	$2.40±0.14^{BC-a}$	$3.07±0.14^{A-a}$	$2.71±0.08^{A-a}$

A-C Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same age) with no common superscripts are significantly different (P<0.05).

increased with temperature to reach a maximum at 27°C, and then decreased between 27 and 34°C. The poor feed conversion ratio at high ambient temperature could be attributed to decreased efficiency of utilization of feed energy for productive purposes (Al-Fataftah, 1987b; Yahav, 1996). Our results also agree with the findings of other researchers (Al-Fataftah, 1987b; Hurwitz *et al*., 1980; Meltzer, 1986).

4.1.5. MORTALITY

Means ± SEM of mortality rate of broilers are shown in table 7. Under both temperatures, fat percentage and feed form did not affect cummulative mortality. Differences in cumulative mortality rate between the two temperatures were also nonsignificant. Quentin *et al*. (2004) also reported that mortality rate of broilers was not affected by pelleting feed. Also, Sinurat and Balnave (1985) found no significant differences in mortality of broilers kept under cyclic high ambient temperatures (25-35°C) compared to those kept under cyclic moderate ambient temperatures (18-26°C). However, these results are in contrast with some of the results found in literature, where mortality increased with pelleted feed compared to mash (Leeson *et al*., 1999), and with heat stress (Smith, 1993b; Teeter and Belay, 1996).

Variations in the results of heat stress experiments are due to many factors, such as heat stress duration, intensity (temperatures used), and type (constant, cyclic or intermittent). Some other factors could be related to the birds, such as age, genetic strain, and body weight. Some genetic advances in the Lohmann strain used in the current study could have taken place over years, making the birds more heat tolerant.

Table 7. Least square means (±SEM) of mortality rate of broilers as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 °C)			Heat stress (35±1 °C)		
	Age (days)			Age (days)		
	28-35	35-42	28-42	28-35	35-42	28-42
2% Fat						
Mash	$0.00 \pm 1.20^{BC-a}$	$8.00 \pm 1.20^{A-a}$	$8.00 \pm 1.08^{BC-a}$	$0.00 \pm 1.20^{A-a}$	$8.00 \pm 1.20^{A-a}$	$8.00 \pm 1.08^{A-a}$
Pelleted	$0.00 \pm 1.20^{BC-a}$	$10.67 \pm 1.20^{A-a}$	$10.67 \pm 1.08^{AC-a}$	$0.00 \pm 1.20^{A-a}$	$8.00 \pm 1.20^{A-a}$	$8.00 \pm 1.08^{A-a}$
4% Fat						
Mash	$0.00 \pm 1.20^{BC-a}$	$10.67 \pm 1.20^{A-a}$	$10.67 \pm 1.08^{AC-a}$	$0.00 \pm 1.20^{A-a}$	$8.00 \pm 1.20^{A-a}$	$8.00 \pm 1.08^{A-a}$
Pelleted	$0.00 \pm 1.20^{BC-a}$	$8.00 \pm 1.20^{A-a}$	$8.00 \pm 1.08^{BC-a}$	$2.67 \pm 1.20^{A-a}$	$10.93 \pm 1.20^{A-a}$	$13.60 \pm 1.08^{A-a}$
6% Fat						
Mash	$1.33 \pm 1.20^{AC-a}$	$10.77 \pm 1.20^{A-a}$	$12.10 \pm 1.08^{AC-a}$	$0.00 \pm 1.20^{A-a}$	$10.67 \pm 1.20^{A-a}$	$10.67 \pm 1.08^{A-a}$
Pelleted	$4.00 \pm 1.20^{A-a}$	$11.17 \pm 1.20^{A-a}$	$15.17 \pm 1.08^{A-a}$	$2.67 \pm 1.20^{A-a}$	$9.67 \pm 1.20^{A-a}$	$12.34 \pm 1.08^{A-a}$

A-C Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same age) with no common superscripts are significantly different (P<0.05).

4.2. CARCASS

4.2.1. CARCASS YIELD

4.2.1.1. HOT CARCASS YIELD

Means ± SEM of hot carcass yield of broilers (dressing percentage and giblets yield) are shown in table 8.

4.2.1.1.1. DRESSING PERCENTAGE

Under natural temperatures, dressing percentage was not affected by fat percentage or feed form. Under heat stress, feed form had no effect, while fat percentage caused an alteration in dressing percentage, which was lower ($P<0.05$) with the pelleted 6% fat diet compared to the pelleted 2% fat diet (73.7 vs. 77.5). However, the highest dressing percentages resulted from the 2% fat diets in both feed forms. This might be explained by higher fat deposition due to higher fat percentage inclusion in the diet, which affects the energy:protein balance, and indirectly affects dressing percentage. Abdelsamie *et al*. (1983) conducted an experiment in which broilers were fed either mash or pelleted feed, and found that dressing percentage was not affected by feed form.

Ambient temperature had no significant effect on dressing percentage. Our results differ from the findings Ain Baziz *et al*. (1996), who reported that heat stress increased dressing percentage, but in agreement with Sonaiya *et al*. (1990), who kept broilers under cyclic high temperature (21-30°C) or under constant low temperature (21°C) and they found that heat stress did not affect dressing percentage.

4.2.1.1.2. GIBLETS

Liver percentage was not affected by any of the different treatments. Heart percentage under heat stress differed with dietary fat percentage, it was higher ($P<0.05$) with the mash 2% fat diet compared to the other fat concentrations in mash diets. Also,

Table 8. Least square means (±SEM) of hot carcass yield of broilers (expressed as a percentage of live body weight) as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)				Heat stress (35±1 ^{o}C)			
	Dressing %	Liver %	Heart %	Gizzard %	Dressing %	Liver %	Heart %	Gizzard %
2% Fat								
Mash	$75.7 \pm 1.02^{A-a}$	$2.2 \pm 0.12^{A-a}$	$0.50 \pm 0.06^{A-b}$	$1.41 \pm 0.08^{A-b}$	$77.1 \pm 1.02^{A-a}$	$2.0 \pm 0.12^{A-a}$	$0.67 \pm 0.06^{A-a}$	$1.88 \pm 0.08^{A-a}$
Pelleted	$76.4 \pm 1.02^{A-a}$	$1.9 \pm 0.12^{A-a}$	$0.53 \pm 0.06^{A-a}$	$1.05 \pm 0.08^{BC-a}$	$77.5 \pm 1.02^{A-a}$	$2.0 \pm 0.12^{A-a}$	$0.54 \pm 0.06^{AC-a}$	$1.24 \pm 0.08^{BC-a}$
4% Fat								
Mash	$76.1 \pm 1.02^{A-a}$	$2.2 \pm 0.12^{A-a}$	$0.56 \pm 0.06^{A-a}$	$1.33 \pm 0.08^{A-a}$	$75.8 \pm 1.02^{AC-a}$	$1.9 \pm 0.12^{A-a}$	$0.36 \pm 0.06^{B-b}$	$1.46 \pm 0.08^{B-a}$
Pelleted	$76.2 \pm 1.02^{A-a}$	$2.2 \pm 0.12^{A-a}$	$0.45 \pm 0.06^{A-a}$	$1.20 \pm 0.08^{AC-a}$	$74.9 \pm 1.02^{AC-a}$	$2.1 \pm 0.12^{A-a}$	$0.43 \pm 0.06^{BC-a}$	$1.26 \pm 0.08^{BC-a}$
6% Fat								
Mash	$75.4 \pm 1.02^{A-a}$	$2.2 \pm 0.12^{A-a}$	$0.58 \pm 0.06^{A-a}$	$1.30 \pm 0.08^{A-a}$	$74.8 \pm 1.02^{AC-a}$	$2.0 \pm 0.12^{A-a}$	$0.39 \pm 0.06^{BC-b}$	$1.28 \pm 0.08^{BC-a}$
Pelleted	$75.8 \pm 1.02^{A-a}$	$2.3 \pm 0.12^{A-a}$	$0.44 \pm 0.06^{A-a}$	$1.19 \pm 0.08^{AC-a}$	$73.7 \pm 1.02^{BC-a}$	$1.9 \pm 0.12^{A-a}$	$0.46 \pm 0.06^{BC-a}$	$1.17 \pm 0.08^{C-a}$

A-C Means in the same column with no common superscripts are significantly different ($P<0.05$).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different ($P<0.05$).

there was a significant difference (P<0.05) between the two ambient temperatures, heat stress resulted in higher heart percentage when the mash 2% fat diet was fed (0.67 vs. 0.50), and lower heart percentage with the mash 4% and 6% fat diets (0.36 vs. 0.56) and (0.39 vs. 0.58) respectively. Gizzard percentage was affected by feed form, it increased (P<0.05) under both temperatures with the mash 2% fat diet compared to the pelleted one, also increased with the mash 2% fat diet under heat stress compared to natural temperature. Under heat stress, increasing fat percentage decreased gizzard percentage, which might be related to consumption of feed of increased concentration of polyunsaturated fatty acids at high temperature. From these results, it could be concluded that ambient temperature did not affect most of the giblets yields in most cases.

Yahav and Hurwitz (1996) found that heart percentage was significantly lower in chickens exposed to 36°C compared to the control birds. Ababneh (2001) studied the effect of high environmental temperatures on chicks carcass characteristics, broilers were reared at constant ambient temperatures of 26, 30, 34, and 38°C, he reported that the birds under ambient temperatures higher than optimal temperature had no significant differences in liver, heart and gizzard percentages.

4.2.1.2. COLD CARCASS (CUTS AND ABDOMINAL FAT) YIELD

Means ± SEM of cold carcass yield of broilers are shown in table 9. Under natural temperature, breast percentage differed (P<0.05) due to fat percentage and feed form. Pelletd feed with 6% fat gave lower breast percentage compared to the 2 or 4% fat diets. Also, it decreased under with the pelleted 6% fat diet compared to the mash diet within the same fat percentage. Under heat stress, breast percentage was affected by dietary fat percentage (P<0.05), it increased with the mash 6% fat diet compared to the mash 2% fat diet, and decreased with the pelleted 2% fat diet compared to the other

Table 9. Least square means (±SEM) of cold carcass yield of broilers (expressed as a percentage of cold carcass weight) as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)				Heat stress (35±1 ^{o}C)			
	Wing %	Breast %	Leg %	Abdominal Fat %	Wing %	Breast %	Leg %	Abdominal Fat %
2% Fat								
Mash	$4.99 \pm 0.13^{AC-a}$	$33.44 \pm 0.82^{A-a}$	$13.70 \pm 0.26^{A-a}$	$2.28 \pm 0.15^{A-a}$	$5.18 \pm 0.13^{A-a}$	$32.45 \pm 0.82^{BC-a}$	$13.95 \pm 0.26^{A-a}$	$2.06 \pm 0.15^{BC-a}$
Pelleted	$4.92 \pm 0.13^{AC-a}$	$34.01 \pm 0.82^{A-a}$	$13.50 \pm 0.26^{A-a}$	$2.22 \pm 0.15^{AC-a}$	$4.88 \pm 0.13^{A-a}$	$30.37 \pm 0.82^{B-b}$	$14.05 \pm 0.26^{A-a}$	$2.41 \pm 0.15^{AC-a}$
4% Fat								
Mash	$5.08 \pm 0.13^{A-a}$	$35.04 \pm 0.82^{A-a}$	$13.34 \pm 0.26^{A-a}$	$1.78 \pm 0.15^{BC-a}$	$5.01 \pm 0.13^{A-a}$	$33.50 \pm 0.82^{AC-a}$	$14.02 \pm 0.26^{A-a}$	$1.77 \pm 0.15^{BD-a}$
Pelleted	$5.10 \pm 0.13^{A-a}$	$32.92 \pm 0.82^{A-a}$	$13.71 \pm 0.26^{A-a}$	$1.62 \pm 0.15^{B-a}$	$4.93 \pm 0.13^{A-a}$	$33.69 \pm 0.82^{AC-a}$	$13.67 \pm 0.26^{A-a}$	$1.78 \pm 0.15^{BD-a}$
6% Fat								
Mash	$5.12 \pm 0.13^{A-a}$	$34.01 \pm 0.82^{A-a}$	$13.67 \pm 0.26^{A-a}$	$1.81 \pm 0.15^{BC-a}$	$5.03 \pm 0.13^{A-a}$	$34.76 \pm 0.82^{A-a}$	$13.61 \pm 0.26^{A-a}$	$1.61 \pm 0.15^{D-a}$
Pelleted	$4.68 \pm 0.13^{BC-b}$	$31.98 \pm 0.82^{B-a}$	$13.83 \pm 0.26^{A-a}$	$2.39 \pm 0.15^{A-a}$	$5.11 \pm 0.13^{A-a}$	$32.71 \pm 0.82^{AC-a}$	$14.16 \pm 0.26^{A-a}$	$2.52 \pm 0.15^{A-a}$

A-DMeans in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

pelleted diets containing higher fat percentage. Increasing the level of fat up to 4% improved breast percentage although this improvement was not significant. In an overall view, ambient temperature did not affect breast percentage, except that the pelleted 2% fat diet resulted in lower breast percentage under heat stress compared to natural temperature..

Leg percentage was not affected by any of the different dietary treatments or ambient temperature. Abdominal fat was affected by dietary fat under both ambient temperatures, it increased ($P<0.05$) with the mash 2% fat diet compared to the other mash diets containing higher fat percentages. The pelleted 6% fat diet resulted in the highest abdominal fat percentage compared to the other pelleted diets. This is reasonable since increasing dietary fat will lead to a higher carcass fat deposition by increasing the energy:protein balance. Under natural temperature and heat stress, pelleted diets increased ($P<0.05$) abdominal fat compared to mash (at the 6% fat level). Moreover, ambient temperature did not have a significant effect on abdominal fat.

Sonaiya *et al*. (1990) found that broilers breast proportion increased, while leg proportion decreased under high cyclic temperature (21-30°C) compared to those reared under constant low temperature (21°C). Mendes *et al*. (1997) found that birds reared under heat stress environment had significantly higher leg yield and abdominal fat, while breast meat yield was lower comparing to the birds grown under thermoneutral conditions.

Our results showed that abdominal fat was not affected by ambient temperature, as was previously reported by Hurwitz *et al*. (1980), and Sinurat and Balnave (1985). They reported no significant effect on abdominal fat content of broilers kept at moderate or high temperature, while many other researchers found that abdominal fat increased with temperature (Yahav *et al*., 1996; Ain Baziz *et al*., 1996; Mendes *et al*., 1997). The

effect of heat on fat deposition could be related to the hormonal control of lipid metabolism, but this could not be fully explained in this study.

4.2.2. CARCASS (MEAT) COMPOSITION

Means ± SEM of leg meat composition of broilers are shown in table 10. Under natural temperature, leg protein was not affected by dietary fat, while tended to increase with pelleted diets compared to mash ($P<0.05$). Under heat stress, higher ($P<0.05$) protein resulted from the pelleted 2% fat diet compared to the other pelleted 4% fat diet. Also from the mash 4% fat diet compared to the pelleted diet containing the same fat percentage (18.63 vs. 17.60). Ambient temperature tended to have no effect on leg protein in general, except a decrease ($P<0.05$) under heat stress compared to natural temperature when the 4% fat diet was fed. Leg fat under natural temperature was lower ($P<0.05$) with the mash 4% fat diet compared to the other mash diets, and compared to the pelleted diet containing the same fat percentage, while under heat stress, the pelleted 4% fat diet resulted in the highest ($P<0.05$) leg fat compared to the other pelleted diets, and compared to the mash diet of the same fat percentage. Ambient temperature also affected leg fat, since it decreased under heat stress with the mash 2% fat and the pelleted 6% fat diets compared to their counterparts under natural temperature. Leg ash content was not affected by ambient temperature.

Means ± SEM of breast meat composition of broilers are shown in table 11. Breast protein under natural temperature was higher ($P<0.05$) with the mash 6% fat diet compared to the other mash diets. Thus, increasing dietary fat percentage in the mash diet increased breast protein, while it was not affected by feed form. Under heat stress, higher ($P<0.05$) protein resulted from the mash 4% fat diet, compared to the mash 6% fat diet. Breast protein was affected by feed form under heat stress, it was higher

Table 10. Least square means (±SEM) of leg meat composition of broilers (on fresh weight basis) as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)				Heat stress (35±1 ^{o}C)			
	Dry Matter %	Protein %	Fat %	Ash %	Dry Matter %	Protein %	Fat %	Ash %
2% Fat								
Mash	25.10±0.06^{D-a}	18.01±0.22^{BD-a}	6.17±0.31^{A-a}	1.01±0.04^{AC-a}	25.24±0.06^{C-a}	18.07±0.22^{AC-a}	4.95±0.31^{B-b}	0.95±0.04^{B-a}
Pelleted	25.41±0.06^{C-a}	18.75±0.22^{AC-a}	5.58±0.31^{A-a}	1.12±0.04^{A-a}	24.42±0.06^{D-b}	18.22±0.22^{A-a}	4.80±0.31^{B-a}	1.05±0.04^{A-a}
4% Fat								
Mash	25.09±0.06^{D-b}	18.41±0.22^{BCD-a}	4.64±0.31^{B-a}	0.95±0.04^{BC-a}	25.29±0.06^{C-a}	18.63±0.22^{A-a}	4.47±0.31^{B-a}	1.05±0.04^{A-a}
Pelleted	25.93±0.06^{A-b}	19.12±0.22^{A-a}	5.59±0.31^{A-a}	1.05±0.04^{AC-a}	26.65±0.06^{A-a}	17.60±0.22^{BC-b}	6.28±0.31^{A-a}	1.02±0.04^{A-a}
6% Fat								
Mash	25.59±0.06^{B-a}	18.27±0.22^{BCD-a}	5.60±0.31^{A-a}	1.11±0.04^{A-a}	25.69±0.06^{C-a}	18.41±0.22^{A-a}	5.20±0.31^{B-a}	1.09±0.04^{A-a}
Pelleted	25.97±0.06^{A-a}	18.52±0.22^{AD-a}	5.64±0.31^{A-a}	1.00±0.04^{AC-a}	24.40±0.06^{D-b}	18.20±0.22^{AC-a}	4.52±0.31^{B-b}	0.98±0.04^{A-a}

A-D Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

Table 11 Least square means (±SEM) of breast meat composition of broilers (on fresh weight basis) as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)				Heat stress (35±1 ^{o}C)			
	Dry Matter %	Protein %	Fat %	Ash %	Dry Matter %	Protein %	Fat %	Ash %
2% Fat								
Mash	24.01±0.02^{F-b}	21.24±0.03^{BC-a}	0.53±0.02^{E-b}	1.26±0.02^{AC-a}	25.65±0.02^{A-a}	21.29±0.03^{AD-a}	0.93±0.02^{B-a}	1.29±0.02^{A-a}
Pelleted	24.13±0.02^{E-b}	21.63±0.03^{BC-a}	0.79±0.02^{B-a}	1.18±0.02^{BC-a}	24.38±0.02^{D-a}	21.10±0.03^{BC-a}	0.66±0.02^{E-b}	1.23±0.02^{AC-a}
4% Fat								
Mash	24.45±0.02^{D-a}	21.71±0.03^{AC-a}	0.79±0.02^{B-a}	1.19±0.02^{BC-a}	24.44±0.02^{D-a}	22.14±0.03^{A-a}	0.81±0.02^{C-a}	1.11±0.02^{B-b}
Pelleted	25.04±0.02^{A-a}	21.20±0.03^{BC-a}	0.99±0.02^{A-a}	1.31±0.02^{A-a}	24.52±0.02^{C-b}	21.84±0.03^{AC-a}	1.02±0.02^{A-a}	1.26±0.02^{AC-a}
6% Fat								
Mash	24.55±0.02^{C-b}	22.63±0.03^{A-a}	0.69±0.02^{C-a}	1.28±0.02^{A-a}	24.90±0.02^{B-a}	20.36±0.03^{BD-b}	0.70±0.02^{DE-a}	1.30±0.02^{A-a}
Pelleted	25.34±0.02^{B-a}	22.58±0.03^{AC-a}	0.62±0.02^{D-b}	1.28±0.02^{A-a}	24.33±0.02^{E-b}	21.59±0.03^{AC-b}	0.74±0.02^{D-a}	1.18±0.02^{BC-b}

A-F Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

($P<0.05$) with mash feed at the 2% fat level, and with pelleted feed at the 6% fat level. Breast protein decreased under heat stress compared with natural temperature when mash and pelleted 6% fat diets were fed. For breast fat percentage, under natural temperature, the highest percentage resulted from the 4% fat diet in both feed forms. Pelleted diets tended to increase breast fat compared to mash (but that was not observed at the 6% fat diet). This indicates that the 4% fat and the pelleted feed gave the most significant results concerning breast fat percentage due to the reason of increasing feed consumption with pelleted feed. Under heat stress, breast fat was higher ($P<0.05$) with the mash 2% fat diet compared to the other mash diets, and with the pelleted 4% fat diet compared to the other pelleted diets. Leg ash percentage decreased under heat stress compared to natural temperature when mash 4% fat and pelleted 6% fat diets were fed. This is attributed to the change in mineral balance due to heat stress.

Some researchers found that heat stress reduced protein (Geraert *et al*., 1996; Yunianto *et al*., 1997; Temim *et al*., 2000), increased dry matter and fat contents of carcass, but ash content was not affected (Geraert *et al*., 1996). Smith (1993b) conducted a study to examine the effects of cyclic high environmental temperature during the growing period on carcass composition. Broilers were reared from 23 to 49 days of age at either 23.9°C constant temperature or 23.9-35°C cyclic temperature. Birds in the hot environment had higher protein and less fat content of thighs and drumsticks, while breast protein was not affected, compared to those reared under thormoneutral conditions.

Ababneh (2001) studied the effect of high environmental temperatures on broilers carcass meat chemical composition. Broilers were reared at constant ambient temperatures of 26, 30, 34, and 38°C. He found that birds reared under ambient temperatures higher than optimal temperature had higher breast fat, thigh and drumstick

protein, and lower breast ash, thigh fat, and breast protein, while thigh and drumstick ash, and drumstick fat were not affected. The nutrient composition of carcass is usually affected by diet composition, that might explain the difference obtained in our study and other studies.

4.2.3. MEAT QUALITY

4.2.3.1. pH AND COLOUR MEASUREMENTS

Means ± SEM of pH and colour measurements of breast meat of broilers are shown in table 12. Breast meat pH tended to decrease ($P<0.05$) under heat stress compared to natural temperature, that was observed with the 2% fat diets in both feed forms, and with the pelleted 6% fat diet. These results are in agreement with the results of Ababneh (2001), who found that broiler chicks under ambient temperatures higher than optimal temperature had lower meat pH. Colour measurements generally were not affected by the different treatments.

4.2.3.2. WATER HOLDING CAPACITY

Means ± SEM of water holding capacity of breast meat of broilers are shown in table 13. Water holding capacity generally was not affected by the different treatments.

4.2.3.3. COOKING LOSS AND SHEAR FORCE MEASUREMENTS

Means ± SEM of cooking loss and shear force measurements of breast meat of broilers are shown in table 13. Shear force under natural temperature was the lowest ($P<0.05$) with the mash 4% fat diet compared to the other mash diets, while under heat stress, at the 2% fat diet, shear force was higher ($P<0.05$) with mash than with pelleted feed. Cooking loss generally was not affected by the different treatments. Sonaiya *et al*. (1990) studied meat quality of male and female broilers reared under cyclic high temperature (21-30°C) or under constant low temperature (21°C), and fed two diets of 13.0 MJ/kg (low energy) or 13.8 MJ/kg (high energy). They found that the different

Table 12. Least square means (±SEM) of some meat quality traits of broilers as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)				Heat stress (35±1 ^{o}C)			
	pH	Lightness	Redness	Yellowness	pH	Lightness	Redness	Yellowness
2% Fat								
Mash	6.62±0.14^{A-a}	4687±136^{A-a}	227±45^{A-a}	1555±112^{AC-a}	5.63±0.14^{A-b}	4676±136^{A-a}	149±45^{A-a}	1556±112^{A-a}
Pelleted	6.32±0.14^{A-a}	4783±136^{A-a}	83±45^{BC-b}	1307±112^{BC-a}	5.65±0.14^{A-b}	4784±136^{A-a}	233±45^{A-a}	1510±112^{A-a}
4% Fat								
Mash	5.62±0.14^{B-a}	4843±136^{A-a}	178±45^{AC-a}	1570±112^{AC-a}	5.72±0.14^{A-a}	4689±136^{A-a}	120±45^{A-a}	1587±112^{A-a}
Pelleted	5.66±0.14^{B-a}	4758±136^{A-a}	163±459^{AC-a}	1476±112^{AC-a}	5.67±0.14^{A-a}	4632±136^{A-a}	139±45^{A-a}	1633±112^{A-a}
6% Fat								
Mash	5.64±0.14^{B-a}	4681±136^{A-a}	130±45^{AC-a}	1524±112^{AC-a}	5.68±0.14^{A-a}	4697±136^{A-a}	209±45^{A-a}	1443±112^{A-a}
Pelleted	6.33±0.14^{A-a}	4557±136^{A-a}	113±45^{AC-a}	1639±112^{A-a}	5.68±0.14^{A-b}	4672±136^{A-a}	138±45^{A-a}	1485±112^{A-a}

A-C Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

Table 13. Least square means (±SEM) of some meat quality traits of broilers as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)			Heat stress (35±1 ^{o}C)		
	Water Holding Capacity %	Cooking Loss %	Shear Force Kg/cm^2	Water Holding Capacity %	Cooking Loss %	Shear Force Kg/cm^2
2% Fat						
Mash	$24.9±2.5^{A-a}$	$27.2±1.3^{A-a}$	$2.8±0.2^{A-a}$	$31.5±2.5^{AC-a}$	$28.8±1.3^{A-a}$	$2.8±0.2^{A-a}$
Pelleted	$26.5±2.5^{A-a}$	$26.6±1.3^{A-a}$	$2.6±0.2^{A-a}$	$26.3±2.5^{BC-a}$	$29.4±1.3^{A-a}$	$2.1±0.2^{BC-a}$
4% Fat						
Mash	$26.8±2.5^{A-a}$	$25.3±1.3^{A-b}$	$2.0±0.2^{BC-a}$	$32.8±2.5^{AC-a}$	$30.9±1.3^{A-a}$	$2.5±0.2^{AC-a}$
Pelleted	$30.6±2.5^{A-a}$	$26.2±1.3^{A-a}$	$2.5±0.2^{AC-a}$	$32.1±2.5^{AC-a}$	$29.7±1.3^{A-a}$	$2.4±0.2^{AC-a}$
6% Fat						
Mash	$26.0±2.5^{A-a}$	$28.5±1.3^{A-a}$	$2.9±0.2^{A-a}$	$37.4±2.5^{A-a}$	$29.0±1.3^{A-a}$	$2.6±0.2^{AC-a}$
Pelleted	$26.4±2.5^{A-a}$	$27.6±1.3^{A-a}$	$2.5±0.2^{AC-a}$	$31.7±2.5^{AC-a}$	$30.3±1.3^{A-a}$	$2.4±0.2^{AC-a}$

A-C Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

factors had no significant effect on cooking losses of the different carcass parts and on the shear force of breast meat samples.

4.3. PHYSIOLOGICAL MEASURES

4.3.1. BLOOD PARAMETERS

Means ± SEM of blood parameters of broilers are shown in table 14**.** Under natural temperature, blood LDL levels decreased with the mash 4% fat diet compared to the mash 2% fat diet, which means that increasing dietary fat level tended to decrease the blood LDL levels, which is desirable for health. The other blood parameters measured (HDL, Cholesterol and triglycerides) were in general not affected by the different treatments. These results are in disagreement with the findings of Gould and Siegel (1985), they studied the effects of short term exposure to high environmental temperature (44-46 °C) on serum lipoprotein in 6 to 7-week-old chickens. They reported that heat exposure lowered both HDL and very low density lipoprotein (VLDL).

Vo *et al*. (1978) studied various blood parameters (red blood cells, hemoglobin, protein and pH) in male and female white leghorn chickens under constant ambient temperatures of 21.2, 29.4 and 35°C from 2 to 31 or 32 weeks of age. They found that all the blood components except pH were reduced with the increase in temperature.

4.3.2. RECTAL TEMPERATURE

Means ± SEM of rectal temperature of broilers are shown in table 15. Rectal temperature was affected by ambient temperature, since it increased ($P<0.05$) with heat stress. Also, under both temperatures, it tended to increase with the increase in dietary fat, and increased with pelleted diets compared to mash in some cases. The increase in rectal temperature represents the bird`s response to the increase in ambient temperature, this is in agreement with many previous studies (Sinurat and Balnave, 1985; Al-Fataftah, 1987a; Servet *et al*., 1997; Gharib *et al*., 2005; Toyomizu *et al*.,

Table 14. Least square means (±SEM) of some blood parameters of broilers as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 ^{o}C)				Heat stress (35±1 ^{o}C)			
	Low Density lipoprotein mg/dl	High Density lipoprotein mg/dl	Cholesterol mg/dl	Triglycerides mg/dl	Low Density lipoprotein mg/dl	High Density lipoprotein mg/dl	Cholesterol mg/dl	Triglycerides mg/dl
2% Fat								
Mash	24.70±3.58^{AC-a}	91.83±6.34^{A-a}	123.17±7.75^{A-a}	22.67±3.69^{AC-a}	18.23±3.58^{AC-a}	102.17±6.34^{A-a}	123.17±7.75^{A-a}	20.17±3.69^{A-a}
Pelleted	27.85±3.58^{A-a}	92.83±6.34^{A-a}	127.83±7.75^{A-a}	29.50±3.69^{A-a}	16.63±3.58^{BC-b}	96.33±6.34^{A-a}	118.83±7.75^{A-a}	30.33±3.69^{A-a}
4% Fat								
Mash	14.40±3.58^{BD-b}	97.00±6.34^{A-a}	116.83±7.75^{A-a}	25.17±3.69^{AC-a}	27.15±3.58^{A-a}	85.67±6.34^{A-a}	119.17±7.75^{A-a}	20.17±3.69^{A-a}
Pelleted	17.75±3.58^{BCD-a}	97.67±6.34^{A-a}	121.50±7.75^{A-a}	17.50±3.69^{BC-a}	23.75±3.58^{AC-a}	91.83±6.34^{A-a}	120.33±7.75^{A-a}	20.83±3.69^{A-a}
6% Fat								
Mash	22.88±3.58^{AD-a}	102.73±6.34^{A-a}	130.83±7.75^{A-a}	20.83±3.69^{AC-a}	18.20±3.58^{AC-a}	99.17±6.34^{A-a}	123.00±7.75^{A-a}	26.67±3.69^{A-a}
Pelleted	13.87±3.58^{BD-a}	89.37±6.34^{A-a}	108.33±7.75^{A-a}	30.33±3.69^{A-a}	15.73±3.58^{BC-a}	90.00±6.34^{A-a}	110.33±7.75^{A-a}	23.83±3.69^{A-a}

A-D Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

Table 15. Least square means (±SEM) of some physiological parameters of broilers as affected by ambient temperature, diatery fat level and feed form.

	Natural Temperature (17-25 °C)				Heat stress (35±1 °C)			
	Age (days)				Age (days)			
	28-35	28-35	35-42	35-42	28-35	28-35	35-42	35-42
	Rectal Temperature °C	Respiratory Rate breaths/minute	Rectal Temperature °C	Respiratory Rate breaths/minute	Rectal Temperature °C	Respiratory Rate breaths/minute	Rectal Temperature °C	Respiratory Rate breaths/minute
2% Fat								
Mash	$40.9\pm0.1^{D-b}$	$58.0\pm0.6^{E-b}$	$41.1\pm0.1^{C-b}$	$60.5\pm0.6^{E-b}$	$41.3\pm0.1^{D-a}$	$117.0\pm0.6^{F-a}$	$42.3\pm0.1^{A-a}$	$117.9\pm0.6^{E-a}$
Pelleted	$41.0\pm0.1^{D-b}$	$62.0\pm0.6^{D-b}$	$41.1\pm0.1^{C-b}$	$62.0\pm0.6^{E-b}$	$41.3\pm0.1^{D-a}$	$120.4\pm0.6^{E-a}$	$42.3\pm0.1^{A-a}$	$118.1\pm0.6^{E-a}$
4% Fat								
Mash	$41.2\pm0.1^{BC-b}$	$62.9\pm0.6^{CD-b}$	$41.2\pm0.1^{B-b}$	$63.8\pm0.6^{D-b}$	$41.6\pm0.1^{C-a}$	$124.0\pm0.6^{D-a}$	$42.3\pm0.1^{A-a}$	121.0 ± 0.6^{D}-a
Pelleted	$41.3\pm0.1^{AC-b}$	$64.3\pm0.6^{C-b}$	$41.3\pm0.1^{A-b}$	$67.6\pm0.6^{C-b}$	$41.9\pm0.1^{B-a}$	$127.1\pm0.6^{C-a}$	$42.3\pm0.1^{A-a}$	$130.4\pm0.6^{C-a}$
6% Fat								
Mash	$41.3\pm0.1^{AC-b}$	$70.3\pm0.6^{B-b}$	$41.3\pm0.1^{A-b}$	$70.9\pm0.6^{B-b}$	$42.2\pm0.1^{A-a}$	$130.7\pm0.6^{B-a}$	$42.4\pm0.1^{A-a}$	$135.1\pm0.6^{B-a}$
Pelleted	$41.4\pm0.1^{A-b}$	$73.2\pm0.6^{A-b}$	$41.3\pm0.1^{A-b}$	$73.4\pm0.6^{A-b}$	$42.3\pm0.1^{A-a}$	$135.0\pm0.6^{A-a}$	$42.4\pm0.1^{A-a}$	$139.2\pm0.6^{A-a}$

A-F Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

2005). Al-Fataftah (1987a) reported that differences in rectal temperature may be due to different metabolic rate or feed intake or genetically determined characters.

4.3.3. RESPIRATORY RATE

Means ± SEM of respiratory rate of broilers are shown in table 15. Respiratory rate increased with ambient temperature ($P<0.05$), and was affected by dietary fat level and feed form in some cases. Consistently, previous studies found similar results with regard to respiratory rate increase under heat exposure (Sykes and Al-Fataftah, 1986; Zhou and Yamamoto, 1997). The change in respiratory rate is one of the physiological effects of heat stress, the increased respiratory rate helps the birds to dissipate heat by evaporative cooling at the surfaces of the mouth and respiratory passageways (Elhadi and Sykes, 1982), in order to keep the increase in rectal temperature within acceptable limits. Toyomizu *et al*. (2005) found that the mean respiratory rate increased from a pre-heat exposure value of 61 breaths/minute to a maximum of 261 breaths/minute after 60 minutes of exposure to 38°C, while El-Hadi and Sykes (1982) found that panting may increase up to 150/minute at 35°C.

4.4. HEAT TOLERANCE TEST

Means ± SEM of the rate of increase of rectal temperature of broilers are shown in table 16**.** Rate of increase of rectal temperature was not affected by the different dietary treatments, but it decreased ($P<0.05$) when the test was conducted after heat exposure of the birds (at the end of the experimental period) compared to the rate observed when the test was conducted without exposing birds to heat prior to the test. which indicates that there was an improvement in the birds heat tolerance, resulting from heat acclimatization of birds acquired during the period prior to the test. The rate of increase of rectal temperature is an expression used by Sykes and Alfataftah (1986) as an indicator of heat tolerance improvement (heat acclimatization).

Table 16. Least square means (±SEM) of the rate of increase of rectal temperature (RITr) of broilers as affected by time of the test, diatery fat level and feed form.

	Rate of Increase of Rectal Temperature (RITr) (^oC/hour)	
	Before heat exposure	After heat exposure
2% Fat		
Mash	4.29^{A-a}	3.30^{A-b}
Pelleted	4.40^{A-a}	3.74^{A-b}
4% Fat		
Mash	3.98^{A-a}	3.29^{A-b}
Pelleted	4.72^{A-a}	3.44^{A-b}
6% Fat		
Mash	4.72^{A-a}	3.73^{A-b}
Pelleted	5.00^{A-a}	3.51^{A-b}

A Means in the same column with no common superscripts are significantly different (P<0.05).
a-b Means in the same row (within the same parameter) with no common superscripts are significantly different (P<0.05).

5. CONCLUSIONS

-Heat stress negatively impacted the main production parameters of broilers even when fat was added to the diet.

-Dietary fat levels with small variations were not enough to cause an improvement in broilers performance under heat stress.

-Feed conversion ratio was not improved by fat addition under heat stress since it follows the same pattern of body weight and feed intake.

-The pelleted feed under natural temperature and 6% fat gave lower breast percentage compared to 2% or 4% fat diets.

-Pelleted feed did not improve broilers performance under heat stress.

-The pelleted 2% fat diet resulted in the highest values of body weight, feed intake and weight gain under heat stress conditions, but the difference was not significant compared to the 4% and 6% fat diets.

-Ambient temperature generally did not affect carcass yields compared to natural temperature.

-Birds will be more heat tolerant if they were exposed to heat prior to heat stress.

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6. RECOMMENDATIONS

-The pelleted 2% fat diet could be used under heat stress.

-Further research is recommended with a wide range of dietary fat levels (exceeding what was used in the current study) under heat stress conditions.

-Further research is recommended to investigate the effect of different fat sources under heat stress conditions, and to compare the effect of these different sources on performance.

-Further research is recommended to study the effects of other different feed strategies and feed manipulations (by using different feed additives), which might be beneficial to alleviate the adverse effects of heat stress.

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تأثير مستويات مختلفة من الطاقة (بإستخدام الدهن النباتي الجاف) وتحبيب العلف على أداء دجاج اللحم المعرض للإجهاد الحراري

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ملخص

تم إجراء التجربة في مزرعة الدواجن في محطة بحوث الأراضي الجافة التابعة للجامعة الأردنيه، لدراسة تأثير مستويات مختلفه من الدهن والشكل الفيزيائي للعليقة على أداء دجاج اللحم المعرض للإجهاد الحراري.

تمت تربية 900 دجاجة من سلالة (Lohmann) من عمر 28-42 يوم، في بداية التجربة تم تقسيم الطيور إلى مجموعتين كل واحدة تضم 450 دجاجة، ربيت إما تحت حرارة المحيط الخارجي (17-25°م) في بيت دواجن مفتوح، أو تحت ظروف الإجهاد الحراري الثابت (35±1°م) في بيت دواجن مغلق، الطيور في كل مجموعة غذيت على ستة علائق تحوي 18% بروتين، مدعمة ب 2، 4، أو 6% دهن نباتي جاف كمصدر للطاقة (لم يتم إضافة زيت الصويا). كل عليقة من العلائق الثلاث أعطيت بشكلين، جريش أو علف محبب.

أظهرت النتائج أن اداء دجاج اللحم انخفض بشكل عام بسبب الإجهاد الحراري، بغض النظر عن نسبه الدهن في العليقة أو شكل العليقة. تحت كلتا الحرارتين، نسبة الدهن في العليقة لم تحسن الأداء (ضمن نفس الشكل الفيزيائي للعليقة). الأداء أيضاً لم يتحسن بتحبيب العلف مقارنة بالجريش (ضمن نفس نسبة الدهن). نسبة التصافي إنخفضت تحت الإجهاد الحراري ($P<0.05$) عندما أعطيت العليقة على شكل علف محبب ونسبة دهن 6%، في حين لم تلحظ فروقات ضمن الحرارة العادية. نسبة الدهون البطنية لم تتأثر بالحرارة المحيطة. المعاملات المختلفة بشكل عام لم تؤثر معنويا على جودة (نوعية) اللحم أو مكونات الدم التي تم قياسها، بإستثناء أن الإجهاد الحراري خفض ($P<0.05$) نسبة الحموضة للحم. كما أظهرت النتائج أن التعرض للحرارة حسن التحمل الحراري لدجاج اللحم.